Laser-induced Single Event Transients at Elevated Temperatures for the LM124 Operational Amplifier

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I. Introduction

Pulsed-laser is a less expensive testing method to examine SEEs in linear bipolar circuits relative to heavy ion testing. Since electronic components in space often operate at a wide range of temperatures, it is necessary to study radiation effects such as SETs at elevated temperatures. The purpose of this experiment is to observe the effects of temperature on laser-induced SETs for the LM124 operational amplifier.

II. Device Description

The device information is given in Table 1. The device specifications are shown in Table 2. Figure 1 shows the detailed circuit diagram. Figure 2 shows a Microphotograph of the circuit layout, with SET sensitive transistors labeled. The sensitive regions were identified in previous experiments [1].

Part Number	XH618ab LM124J
LDC	036AD
Manufacturer	National Semiconductor
Package	DIP 14
Function	Operational amplifier
Technology	Linear bipolar
Previous Testing	Part previously tested by laser irradiation at room temperature [1]

Table 1. Device description.

Parameter	Condition	Min	Max	Unit
Operating temperature (T_A)		-55	125	^oC
Rise time (TR)	$V_{cc}^+ = 30$ V, $V_{cc}^- =$ Gnd		1.0	μs
Slew rate S_R	$V_{cc}^+ = 30$ V, $V_{cc}^- =$ Gnd	0.1		V/ μs
Output voltage (V_{OP})	$V_{cc}^+ = 30$ V, $V_{cc}^- =$ Gnd $V_o = 30$ V, $R_L = 10$ kΩ	27		V

Table 2. Device specifications.

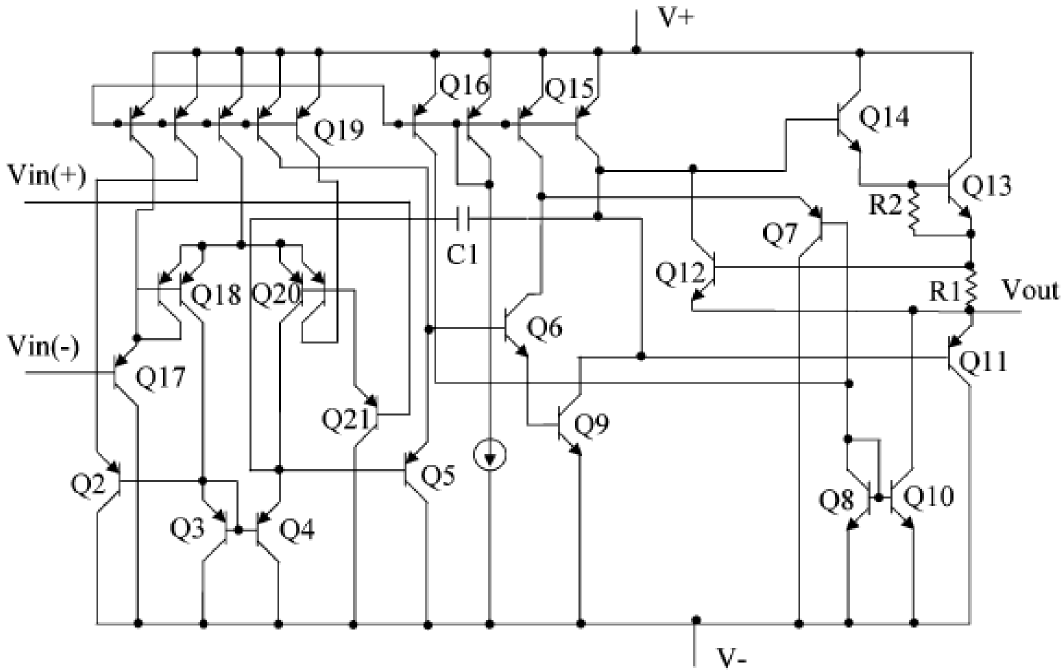

Figure 1. Circuit schematic of the LM124 showing Q19 with 5 transistors, Q15, Q16, Q18, and Q20 with 2 transistors each [1].

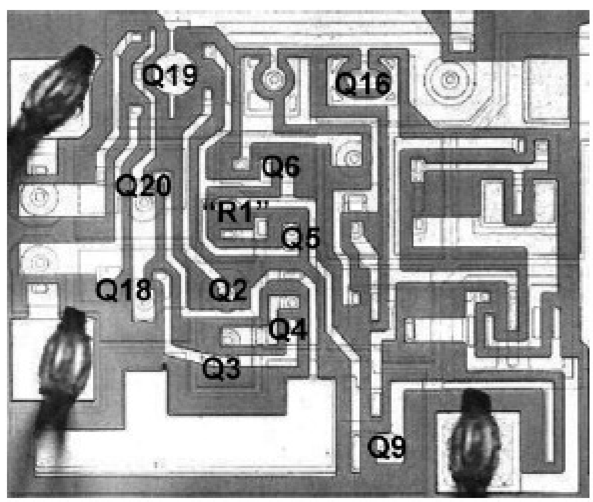

Figure 2. Microphotograph of the LM124 with sensitive regions labeled [1].

III. Test Facility

The testing was conducted at the Naval Research Laboratory with a YLF laser. The laser beam characteristics are listed in Table 3 below.

Table 3. Laser characteristics.

Wave Length	590 nm
1/e penetration depth	2 µm
Beam diameter	1.7 µm

IV. Test Conditions

Testing Temperature: Room temperature, 50°C, 75°C, 100°C, and 120°C.
Power supply (V_{cc}): $V_{cc}+ = 5$ V, $V_{cc}- = -5$ V.
Input voltage (V_{in}): ~ 0.13 V.
Parameters of interest: Amplitude and width of SETs. The oscilloscope will be preset to trigger at 200 mV. The trigger voltage level will be adjusted appropriately according to the transient levels observed during the experiment.

A block diagram of the test setup is shown in Figure 5. A power supply provides power and input voltages to the device. The oscilloscope is connected to the output to monitor the output voltage levels, and record any SETs above the threshold. The elevated temperature test setup requires a power supply, multimeter, thermal pad, and thermistor. The power supply outputs voltage to the thermal pad, which is attached to the device. The temperature increases as the voltage is increased. A multimeter measures the resistance of the device through a thermistor, which is also attached to the device. The resistance is converted into temperature by a program controlled by a laptop computer. The computer manages the amount of power applied to the device and the temperature of the device.

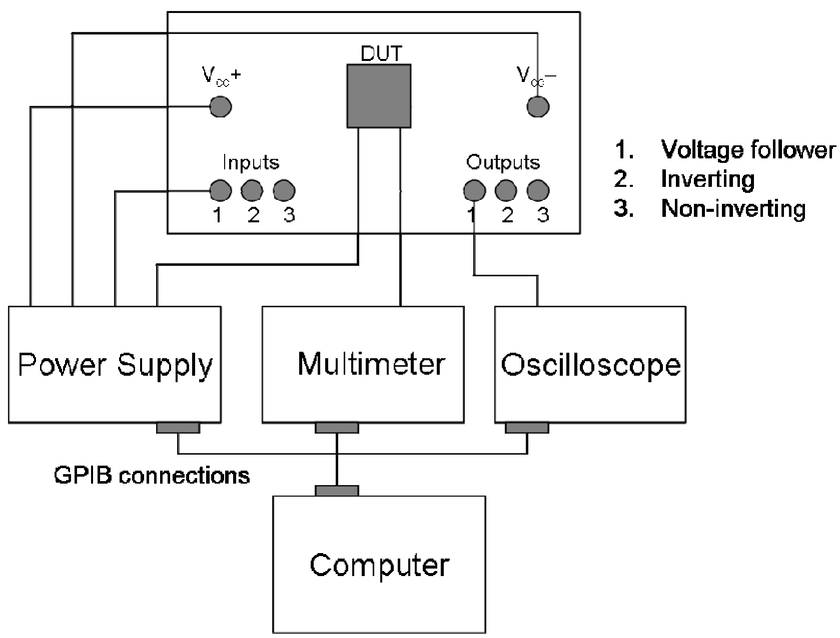

Figure 5. Block diagram of the test setup.

The device was heated to a set temperature. After the temperature stabilizes, the sensitive areas, Q9, Q11, Q14, Q19, and R1 as identified in Figure 2, were irradiated by pulsed-laser. The resulting transients were recorded. The process was repeated for the next temperature step.

V. Results

The LM 124 was configured with V_{CC+} = 5 V, V_{CC-} = -5 V, V_{IN} ~ 0.1 V, as a voltage follower and an inverter with gain of 10. With increasing temperature, we observed broadening of SET pulse widths for transistors Q9, Q19 and Q14. The slope of the recovery edge did not change for different temperatures. Figure 8 summarizes the change in pulse widths with temperature for various transistors in the voltage follower and inverter with gain configurations. The increase in pulse widths were approximately 1 μs for Q9 and Q19 in both the voltage follower and inverter configurations. The pulse broadening was most significant for Q14 in the inverter configuration with an increase of ~ 2.5 μs (45%). Transistor Q14 is the first stage of the Darlington pair structure. The amplification caused by the Darlington structure and the location near the output result in the significant increases to the SET pulse widths from transistor Q14. In contrast transistor Q11 was relatively insensitive to SETs. R1 exhibited decreasing amplitudes with increasing temperature.

As shown in Figure 4, R1 also exhibits bipolar characteristics, with a secondary negative-going component. The amplitude of the additional component also decreases in magnitude with increasing temperature. The SETs from R1 in the voltage follower configuration exhibits markedly different behaviors, as shown in Figure 3. The pulse shapes are relatively unaffected by temperature. We observed a slight hump on the falling edge of the transients, which become more prominent with increasing temperature. The hump is likely due to charges collected from the feed-back response, similar to the perturbation that appears following the initial peak in other transistors.

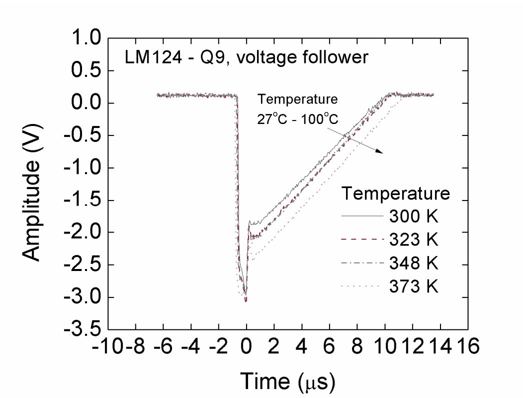

Figure 1. Q9 – voltage follower.

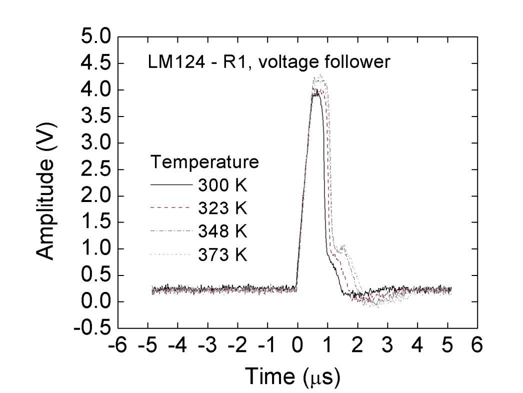

Figure 3. R1 – voltage follower.

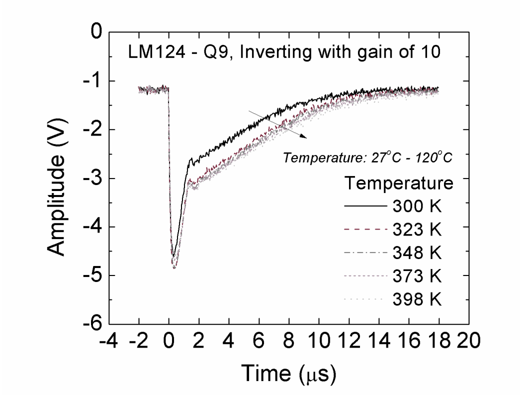

Figure 2. Q9 – inverter with gain of 10.

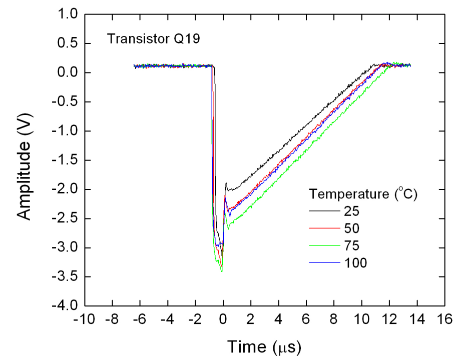

Figure 7. Q19 – voltage follower.

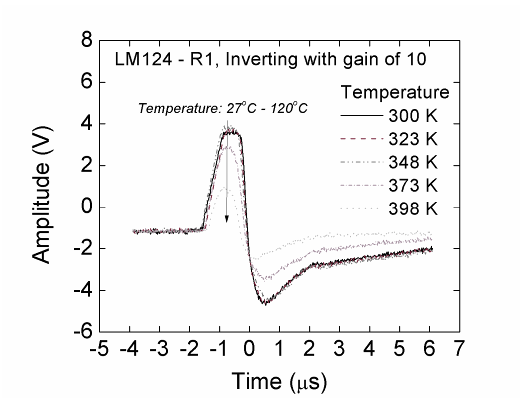

Figure 4. R1 – inverter with gain of 10.

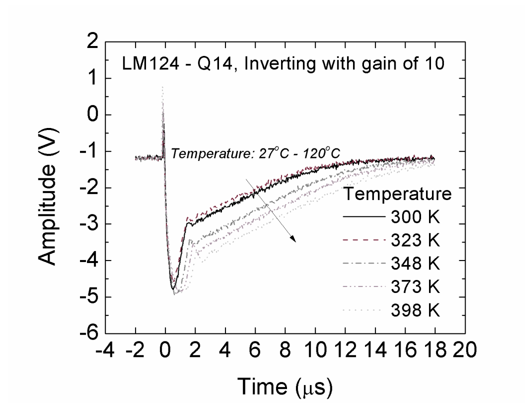

Figure 6. Q14 – inverter with gain of 10.

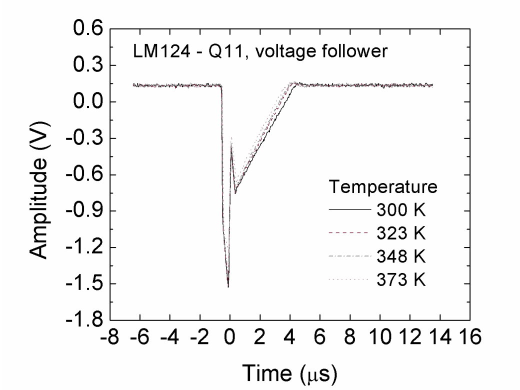

Figure 5. Q11– voltage follower.

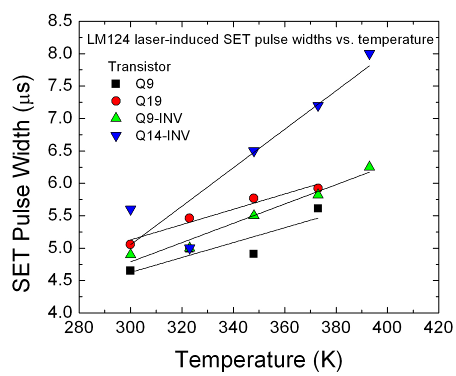

Figure 8. SET pulse width vs. temperature for transistors in the LM124 configured as a voltage follower and an inverter with gain of 10.

VI. Conclusion

The pulse shapes for Q9, Q11, Q14 and Q19 exhibited a sharp initial transient followed by a gradual recovery phase with a gentler slope, similar to previous results [1].

We found that the pulse widths increased with increasing temperature for Q9, Q19, and Q14. The magnitude of pulse broadening was most significant for Q14 in the inverter configuration, where the pulse width increased by ~2.5 µs (45%) from 27^{o}C to 120^{o}C. The temperature effects may be a concern for radiation hardness, depending on application.

VII. Reference

[1] S. Buchner et al., "Comparison of Single-Event Transients Induced in an Operational Amplifier (LM124) by Pulsed Laser Light and a Broad Beam of Heavy Ions," *IEEE Trans. Nucl. Sci*., vol 51, pp. 2776-2781, 2004.